

METHOD, ARTICLE OF MANUFACTURE AND SYSTEM

5 TO DETERMINE A BIT RATE OF A SIGNAL

BACKGROUND INFORMATION

This invention relates generally to determining the bit rate of a signal. Digital signals are formatted to have different bit rates. For example, in telephony equipment, digital signals may be 2.048 MHz, 4.096 MHz or 8.092 MHz. In order for digital equipment to properly communicate via digital signals, the bit rate must be known. One existing method of determining the bit rate is to identify the piece of equipment to which a connection is desired, and then consult with the manufacturer of that equipment to obtain the bit rate at which that equipment operates. Accordingly, in contrast to the foregoing method, automatically detecting the bit rate of a signal would be highly desirable.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the nature and objects of the invention, reference should be made to the following detailed description taken in conjunction with the accompanying drawings, in which:

Figures 1A and 1B are a block flow diagram in accordance with one embodiment of the invention;

Figures 2A and 2B are a block flow diagram in accordance with one embodiment of the invention; and

Figure 3 illustrates a system and an article of manufacture according to an embodiment of the invention.

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DETAILED DESCRIPTION

An embodiment of the invention analyzes a signal to automatically detect the bit rate of the signal. For example, a digital signal having logical events, for example logical ones and logical zeros, is received. A plurality of durations are determined, each duration corresponding to elapsed time between logical events of the signal, for example between a first logical one and a second logical one. A first counter is incremented for each occurrence of a first duration to provide a first total value. A second counter is incremented for each occurrence of a second duration to provide a second total value. The second duration may correspond to the selected duration plus a time interval. Then the bit rate of the signal is determined using a weighted average corresponding to the first and second values.

Figures 1A and 1B illustrate a method according to the invention. A signal of interest, having logical ones and logical zeros, may be received **100**. A time measuring device, which may include the system clock of

a computer, is provided **103**. The time measuring device may be capable of counting a number of time intervals to provide an amount of time. For example, one time interval may be one output or oscillation of the system clock, and the amount of time may be the cumulative total number of outputs or oscillations of the system clock detected from occurrence of a first action or event to the occurrence of a second action or event.

A plurality of durations may be determined **106** using the time measuring device. Each duration may correspond to an amount of time elapsed between events, such as detection of a first logical one and detection of a second logical one. For example, a duration may be determined by starting the time measuring device upon detecting a transition from a logical zero to a logical one in the signal. The time measuring device counts the system clock oscillations until the time measuring device is instructed to stop counting. The time measuring device may be instructed to stop counting when a subsequent transition from a logical zero to a logical one in the signal is detected.

Detection of logical events may be performed by sensing a change in the signal's voltage from a reference voltage to a voltage indicative of a logical one. The change from a reference voltage to a voltage

indicative of a logical one is referred to herein as the "leading edge of a pulse" or the "leading edge of a logical one". The leading edge of a logical one may be thought of as the end of a logical zero.

5 Other methods of detecting logical events may be employed. For example, by sensing a change in the signal's voltage from a voltage indicative of a logical one to a reference voltage, a so called "trailing edge of a pulse" or "trailing edge of a logical one" may be
10 detected. With this in mind, an embodiment of the invention is described herein where the leading edge of a pulse is detected, but the invention is not limited to this embodiment.

After a plurality of durations have been
15 determined, one of the plurality of durations is selected **109**. In one embodiment of the invention, the selected duration is the shortest of the plurality of durations. For example, if a duration of 16 system clock oscillations is determined 100 times, and a
20 duration of 17 system clock oscillations is determined 500 times, and a duration of 25 system clock oscillations is determined 5 times, the selected duration is 16 system clocks.

A first total value may be determined by counting
25 durations **112** among the plurality of durations that are

approximately equivalent to the selected duration. The first total value is the number of times the selected duration is among the plurality of durations. Using the example above, the first total value would be 100.

5 Since it is likely the time measuring device is not synchronized with the signal, the selected duration may not accurately correspond to the bit rate of the signal. Therefore, information corresponding to a second duration, and possibly a third duration (or more) may be
10 selected for further analysis. If so, a second total value is determined by counting durations **118** among the plurality of durations that correspond to the second duration. The second total value corresponds to the number of times the second duration is found in the
15 plurality of durations. The second duration may be approximately equivalent to the selected duration plus one time interval. For example, if the selected duration is 16 system clock oscillations, then the second duration is 17 system clock oscillations. In the
20 example given above, the duration of 17 system clock oscillations was detected 500 times, and so the second total value would be 500.

 A third total value may be determined, if needed, by counting durations among the plurality of durations
25 that correspond to the third duration. The third total

value corresponds to the number of times the third duration is found in the plurality of durations. The third duration may be approximately equivalent to the selected duration plus two time intervals. Therefore, in the example given above, the third duration would be 18 system clock oscillations, and since no duration among the plurality of durations was 18 system clock oscillations in length, the third total value is zero.

The total values may each be determined by setting a counter to zero, evaluating each duration of the plurality of durations, and incrementing the counter for each duration that corresponds to the selected duration, second duration or third duration, as the case may be.

If more durations than the selected duration are determined, a weighted average is determined **121**. The weighted average may be calculated by multiplying the selected and the determined durations by their corresponding total value to provide a product corresponding to each duration. Then these products are summed to provide a sum of products, and a sum of the corresponding total values is determined. Then the weighted average is determined by dividing the sum of products by the sum of the total values. In the example described above, the first product is $16 \times 100 = 1,600$, the second product is $17 \times 500 = 8,500$ and the third

product is $18 \times 0 = 0$. The sum of the products is $1,600 + 8,500 + 0 = 10,100$. The sum of the total values is $100 + 500 + 0 = 600$, and the weighted average is $10,100 \div 600 = 16.833$.

5 Next, the bit rate of the signal may be set **124**
using the mathematical inverse of the selected duration,
or the mathematical inverse of the weighted average, if
the weighted average was determined. If the signal is
known to represent immediately consecutive logical ones
10 with a change in the signal, but represents immediately
consecutive logical zeros without a change in the
signal, such as in an alternate mark inversion ("AMI")
signal, then the bit rate is set to the mathematical
inverse of the weighted average. However, if the signal
15 is known to represent immediately consecutive logical
ones without a change in the signal, such as in a
unipolar NRZ ("non-return to zero") signal or a bipolar
NRZ signal, then the bit rate is set to the mathematical
inverse of one-half of the weighted average. Using the
20 example given above, if the signal is known to be an AMI
signal, the bit rate would be set to $1 \div 16.833 = 0.0594$
bits per system clock oscillation. However, if the
signal is known to be a unipolar NRZ signal, then the
bit rate would be set to $1 \div (16.833 \div 2) = 0.1188$ bits
25 per system clock oscillation.

If the time interval of the time measuring device is known, for example the oscillation rate of the system clock is 16 MHz, then the bit rate may be converted into another time measurement system, for example bits per
5 second. If the oscillation rate of the time measuring device is 16 million oscillations per second, then a bit rate of 0.1188 bits per system clock oscillation would be set to 1,900,990.1 bits per second.

In some situations, the shortest duration is not
10 the duration that should be selected. For example, noise in the signal may provide a number of durations that are shorter than the shortest determined duration corresponding to the signal. Therefore, it may be necessary to eliminate those determined durations that
15 are not likely to correspond to the signal. One method of doing so involves setting a threshold value and comparing the first total value to the threshold value. If the first total value is less than the threshold value, the next shortest duration may be selected from
20 among the plurality of durations, and the method proceeds as described above to determine a first total value corresponding to the selected duration, however now the selected duration is not the shortest duration, but is instead the next shortest duration among the
25 plurality of durations. This process of comparing the

first total value to the threshold, and selecting the next shortest duration if the selected duration is less than the threshold, continues until the selected duration has a corresponding total value that is not
5 less than the threshold.

The threshold may be a preselected number or the threshold may be set depending on the number of durations determined. For example, the threshold may be some percentage, for example 2%, of the total number of
10 durations determined.

In another embodiment of the invention, illustrated in Figures 2A and 2B, a signal having logical ones and logical zeros is received **200**, and a time measuring device that is capable of measuring an amount of time in
15 time intervals may be provided **203**. Then the time measuring device may be used to determine **206** a duration corresponding to the signal. As before, the duration may correspond to an elapsed time between detection of an initial logical one and detection of a subsequent
20 logical one. A plurality of counters may be provided **209**. The counters may initially be set to zero, and the counters may correspond to expected durations of time. One of the counters corresponding to the determined duration is incremented **212** to provide a total value
25 corresponding to the determined duration. The process

of determining a duration **206** corresponding to the
signal, and then incrementing a counter **212**
corresponding to the determined duration, may be
repeated **215** until a desired number of durations have
5 been determined and counted.

Then a first duration may be selected **218** from
among the determined durations. The first duration may
be the shortest of the durations determined and counted.
The total value from the counter corresponding to the
10 first duration is selected **221**. As described above, a
second duration that is one time interval greater than
the first duration may be selected **227**, and the total
value provided by the counter corresponding to the
second duration is selected **230** as a second total value.
15 As described above, a third duration, which corresponds
to the first duration plus two time intervals, may also
be selected, and a third total value corresponding to
the third duration is selected.

Once the durations and corresponding total values
20 are selected, the weighted average may be determined
233. The weighted average may be computed as described
above. Then, a bit rate may be set **236** using the
mathematical inverse of the weighted average, as
described above.

As in the previously described embodiment, the time measuring device may include an oscillator having a known oscillation rate. Furthermore, determining a duration may include counting the number of oscillations
5 between detection of the initial logical one and detection of the subsequent logical one, as described above. Also, as described above, the first total value may be compared to a threshold value in order to determine **224** whether a new first duration should be
10 selected.

One embodiment of the invention may include a check of the determined bit rate. For example, if the signal is known to be an alternate mark inversion ("AMI") signal, the weighted average will correspond to the
15 duration measured when the second logical one immediately follows the first logical one. The AMI signal will probably provide a logical one, immediately followed by a logical zero and then a logical one. Therefore, the duration determined when a first logical
20 one is followed immediately by a logical zero and then immediately by a logical one may be twice that determined when two logical ones are received without the intervening logical zero. Consequently, to check that the proper bit rate for the AMI signal has been
25 determined, it may be determined whether the durations

corresponding to half of the determined bit rate have corresponding total values that are more than zero, or above a threshold value, as the case may be. A similar check may be made for other types of signals, such as the unipolar NRZ signal and the bipolar NRZ signal discussed above. In these NRZ signals, if the bit rate is properly determined, the durations corresponding to one-third of the determined bit rate should have corresponding total values that are more than zero, or above the threshold value, as the case may be.

It may be appreciated that the ability to accurately determine the bit rate of the signal may be diminished when the time intervals of the time measuring device are large relative to the signal bit rate. On the other hand, when the time intervals of the time measuring device are small relative to the signal bit rate, the ability to accurately determine the signal bit rate is increased. It is therefore possible that, given a time measuring device with sufficiently small time intervals (e.g. a high oscillation rate), three durations and three corresponding total values need not be selected in order to provide a sufficiently accurate bit rate. For example, if the time intervals of the time measuring device are sufficiently small, the bit rate could be accurately determined using two durations

and two corresponding total values. However, if the time intervals of the time measuring device are large relative to the bit rate, then more than three durations and three corresponding total values may be needed to accurately determine the bit rate.

An embodiment of the invention may be implemented by a system **300** illustrated in Figure 3. The system **300** includes a computer **301** having computer software running thereon. A system clock of the computer **301** may be used as a time measuring device. The time measuring device assists the computer **301** in determining each duration by identifying intervals of time to the computer. The computer **301** may be connected via a connection line **303** to a transmission line **306** carrying the signal for which a bit rate must be determined. The computer software may be stored on an article of manufacture **309**, such as a computer readable storage medium, for example a compact-disc, and loaded onto the computer **301**, for example via a compact-disc drive **312**. In such a system, the computer **301** may not be able to capture data on each duration, but over time, the computer **301** should be able to gather a representative sample of information on the durations provided by the signal.

The computer software has computer readable program code instructions to cause a computer **301** to determine a bit rate of a signal. Portions of the instructions may be thought of as computer readable program code modules to cause the computer **301** to carry out the methods described above. One such code module that may be provided is capable of causing the computer **301** to determine a plurality of durations, each duration corresponding to an elapsed time between detection of a first logical one and detection of a second logical one of a signal. This code module may include instructions that cause the computer to count time intervals occurring between detection of the first logical one and detection of the second logical one.

The instructions may also include a code module capable of causing the computer **301** to select a duration from among the plurality of durations. The selected duration may be the shortest of the plurality of durations. In addition, a code module may be provided that is capable of causing the computer **301** to count those durations that are approximately equivalent to the selected duration to provide a first total value, and causing the computer **301** to count those durations that are approximately equivalent to a second duration to provide a second total value, the second duration

corresponding to the selected duration plus one time interval.

In addition, the instructions may include a code module to cause the computer **301** to determine a weighted
5 average corresponding to the first and the second total values, and to the selected duration and the second duration. The instructions may also include a code module that is capable of causing the computer **301** to
10 set a bit rate of the signal using a mathematical inverse of the weighted average.

A code module may be capable of causing the computer **301** to determine whether the first total value is less than a threshold value. If the first total value is less than the threshold value, the code module
15 causes the computer **301** to select another duration from among the plurality of durations, and that duration may be the next shortest of the plurality of durations.

The code module for causing the computer **301** to count durations and provide the first total value may
20 include instructions that cause the computer **301** to set a counter to zero prior to evaluating the durations, and instructions that cause the computer **301** to evaluate each duration of the plurality of durations to determine whether each duration is approximately equivalent to the
25 selected duration. Furthermore, a code module may be

provided that is capable of causing the computer **301** to increment the counter for each duration that corresponds to the selected duration.

The code module for causing the computer **301** to
5 determine the weighted average may have a instructions
to cause the computer **301** to multiply the selected
duration by the first total value to provide a first
product, and to cause the computer **301** to multiply the
second duration by the second total value to provide a
10 second product. A code module may also be capable of
causing the computer **301** to add the first product and
the second product to provide a sum of the products. In
addition, a code module may be capable of causing the
computer **301** to add the first total value to the second
15 total value to provide a sum of the total values, and
for causing the computer **301** to divide the sum of the
products by the sum of the total values to determine the
weighted average.

Once the bit rate of the signal is known, devices
20 may be programed to receive and interpret the signal.
Although the invention has been described with respect
to one or more particular embodiments, it will be
understood that other embodiments of the invention may
be made without departing from the spirit and scope of
25 the invention.